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Amazon fisheries
II – Variations in the relative abundance of tucunaré (*Cichla ocellaris, C. temensis*) based on catch and effort data of the trident fisheries

by

Miguel Petrere Jr.

Dr. Miguel Petrere Jr., UNESP, Departamento de Ecologia, 13.500 Rio Claro - SP, Brasil.
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Abstract

In this paper, the application of analysis of covariance on catch and effort data from seven lakes located at different distances shows that the adjusted mean catches, which are calculated discounting the effect of the average fishing effort increase as further is the lake from Manaus. Effects on the interactions between lake and season (and also between lake and year) are discussed according to lake morphology and fish behaviour.

Keywords: **River ecology, floodplain fisheries, analysis of covariance, *Cichla* spp.**

Resumo

Neste trabalho, a aplicação da análise de covariância em dados de captura e esforço de pesca referente a sete lagos localizados no Estado do Amazonas mostra que as médias ajustadas das capturas, que são calculadas descontando o efeito do esforço de pesca médio, aumentam com a distância do lago em relação a Manaus. Os efeitos da interação entre lago e estação (e tambem entre lago e ano) são discutidos de acordo com a morfologia do lago e o comportamento do peixe.

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1. Introduction

In this paper the relationship between catch, and fishing effort of tucunaré caught by trident, is examined in relation to the lake in which the fish were caught, the season and the year of capture. The results are discussed also in relation to the distances of the lakes from Manaus (capital of the Amazonas state) and the season of the year. Historical aspects of the fishery are also considered together with the learning behaviour of populations under long periods of exploitation which would decrease their catchability. A Factorial Analysis of Multiple Covariance (FAMC-model) was used to interpret the results.

2. Methods

2.1 Data

The lakes in table 1 were taken for analysis.

The catch of tucunaré (in kg), caught in the years 1976, 1977 and 1978 by trident was extracted from the data set of these lakes. The tucunaré is also caught by gillnets, rod and line, etc. So we are here considering only a subsample of the data set. See PETRERE (1978) for a description of data collection.

Table 1: Name of the lakes and distance (d - km) from Manaus.
The geographical positions are shown in PETRERE (1978).
W - white water, B - black water.

Order number	Lake	d (km)
1	Rei	85 W
2	Janauacá	100 W
3	Piranha	138 B
4	Manaquiri	140 W
5	Manacapuru	250 B
6	Aiapuá	374 W
7	Badajós	483 B

The tucunaré includes at least two species: *Cichla ocellaris* locally known as tucunaré comum, potoca, popoca, botão or azul (blue); *Cichla temensis* locally known as tucunaré açu or paca. The name 'tucunaré sarabiana' may be applied to both species by certain fishermen (P. B. BAYLEY, personal communication).

Cichla ocellaris was the commonest species landed at Manaus market during 1976, 1977 and 1978; the fishermen from the Manaus fishing fleet referred to it more frequently as tucunaré potoca.

The average size of *Cichla ocellaris* at Manaus market until 1978 was between 35 - 40 cm. ZARET (1980) observed a *Cichla ocellaris* at Manaus measuring 70 cm TL (9 kg). A *Cichla ocellaris* measuring 45 cm TL weighed 1280 g and a *Cichla temensis* of the same size, 1250 g. A *Cichla temensis* of 55 cm TL weighed 2500 g.

The tucunaré is a fish predator LOWE-McCONNELL (1969) and when larger than 4 cm total length eat fish and prawns (*Macrobrachium* spp.) but rarely other animals (P. B. BAYLEY, personal communication). GOULDING (1980) observed that among nine tucunarés caught in the Rio Machado (State of Rondônia), eight contained fish in their stomach, although he does not comment of the stomach contents of the other one. The tucunaré spawn in lakes.

For purpose of analysis the year is divided into two different seasons:

(a) high water season – includes the months of May, June and July for the three years.

(b) low water season – includes the months of October, November and December for 1976 and 1978 and the months of September, October and November for 1977.

As shown in Figure 1 it can be seen that the months immediately preceding and succeeding the low or high water peak month, together with the peak month were considered as the season.

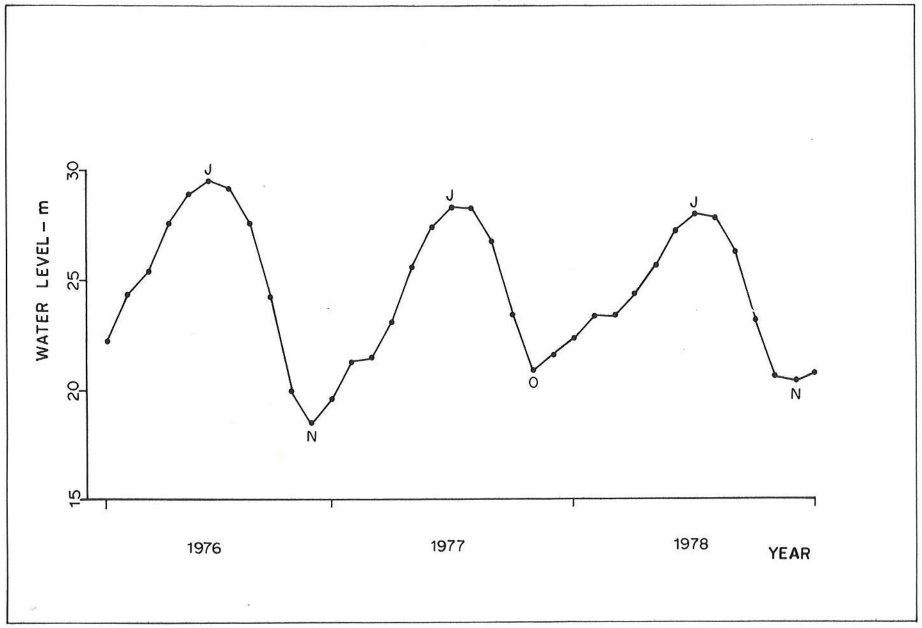

Fig. 1:
Monthly average heights of the Rio Negro at Manaus from 1976 to 1978.

The year is devided into these two rather artificial seasons because the fishery in each season has different characteristics. In the high water season the fishes are more dispersed through the environment, theoretically the average density of the stocks in each lake is lower and the fishermen must search a greater area of the expanded environment for the fish. In both seasons the tucunaré is caught during the night by the trident when the fishermen spot the fish using a torch, as explained in PETRERE (1978). Although the catchability is not supposed to remain constant between such contrasting seasons, it does not matter for the FAMC-model to be adopted because this excess of variability would be incorporated in the residual variance of the error line.

2.2 The statistical model adopted:

The catch of the tucunaré (in kg), the number of trips, the product of number of fishermen x days of fishing were calculated for each lake and season for each year. After the examination of the scatter plots, the relationship between the catches and the two units of fishing effort and between the units of efforts themselves is taken as linear after a square root transformation. The following statistical model can then be applied:

$$Y_{ijk} = \mu + \alpha_i + \pi_j + \gamma_k + (\alpha \cdot \pi)_{ij} + (\alpha \cdot \gamma)_{ik} + (\pi \cdot \gamma)_{jk} + \beta_1 (X_{1\,ijk} - \overline{X}_1) + \beta_2 (X_{2\,ijk} - \overline{X}_2) + \epsilon_{ijk} \qquad \text{Equation 1}$$

where for each i = 1, 2, 3 (year); j = 1, 2, . . ., 7 (lake); k = 1, 2 (season).

Y_{ijk} = SQRT (catch, in kg, per season
μ = overall mean
α_i = effect of the year, at level i
π_j = effect of the lake, at level j
γ_k = effect of the season, at level k
X_1 = SQRT (number of trips), per season
X_2 = SQRT (number of fishermen x days of fishing), per season

$(\alpha \cdot \pi)_{ij}$ – denote the interaction between the effect of the year at level i and the lake at level j

$(\alpha \cdot \gamma)_{ik}$ – denote the interaction between the effect of the year at level i and the season at level j

$(\pi \cdot \gamma)_{jk}$ – denote the interaction between the effect of the lake at level j and the season at level k

ϵ_{ijk} – denote a random variate supposed N $(0, \sigma^2)$

PETRERE (this volume) discuss fully the applications of the FAMC-model in observational data.

3. Results

Table 2 displays the raw data to which the FAMC-model was applied.

Figures 2 - 4 show the plot of the dependent variate against the independent ones and between the independent ones respectively, as defined previously. Since these patterns can be taken as linear, the FAMC-model was applied and the validity of the procedure can be judged by the examination of the residuals.

Table 3 shows the application of the FAMC-model applied to the data of Table 2.

Table 2: Catch-effort data from the seven lakes from Table 1. Tucunaré.
1. Lake Rei; 2. Lake Janauacá; 3. Lake Piranha; 4. Lake Manaquiri; 5. Lake Manacapuru; 6. Lake Aiapuá; 7. Lake Badajós; I. High water season; II. Low water season; NT - number of trips per season; NF - number of fishermen x days of fishing per season.

Year	Lake	Season	NT	NF	Catch (kg)
76	1	I	64	2316	21815
6	2	I	46	2228	19129
6	3	I	28	1501	16009
6	4	I	6	280	3107
6	5	I	2	70	1528
6	6	I	1	80	3170
6	7	I	26	1634	23797
6	1	II	25	600	10171
6	2	II	12	366	3925
6	3	II	4	130	3046
6	4	II	4	130	1418
6	5	II	2	112	1752
6	6	II	3	125	4046
6	7	II	8	395	7032

Table 2: Continuation

Year	Lake	Season	NT	NF	Catch (kg)
77	1	I	100	2712	26481
7	2	I	34	1162	8281
7	3	I	24	1129	9566
7	4	I	5	299	2958
7	5	I	1	48	223
7	6	I	1	35	536
7	7	I	25	1679	19219
7	1	II	38	1078	9691
7	2	II	17	649	5656
7	3	II	9	521	4872
7	4	II	11	471	5200
7	5	II	2	68	491
7	6	II	4	314	3653
7	7	II	16	906	11369
78	1	I	63	1910	18835
8	2	I	36	1240	8762
8	3	I	18	988	8395
8	4	I	5	152	1672
8	5	I	4	81	1310
8	6	I	1	126	1071
8	7	I	17	993	11603
8	1	II	74	1889	35822
8	2	II	32	1130	16612
8	3	II	22	983	17015
8	4	II	6	138	1712
8	5	II	1	30	315
8	6	II	3	166	1930
8	7	II	12	669	10996

3.1 Factorial ANOVA of the covariates and response variate

In Table 3, rows 1 to 8 and columns 1 and 2, were examined by applying a Factorial ANOVA to the covariates. Column 6 is used for the response variate; the calculations are shown in Table 4.

These results show that the fishing effort is not homogeneously distributed between the lakes and season for X_1 and X_2 and that for X_2 the effect of year and lake are not independent from season. The result for the response variate (Y) is similar.

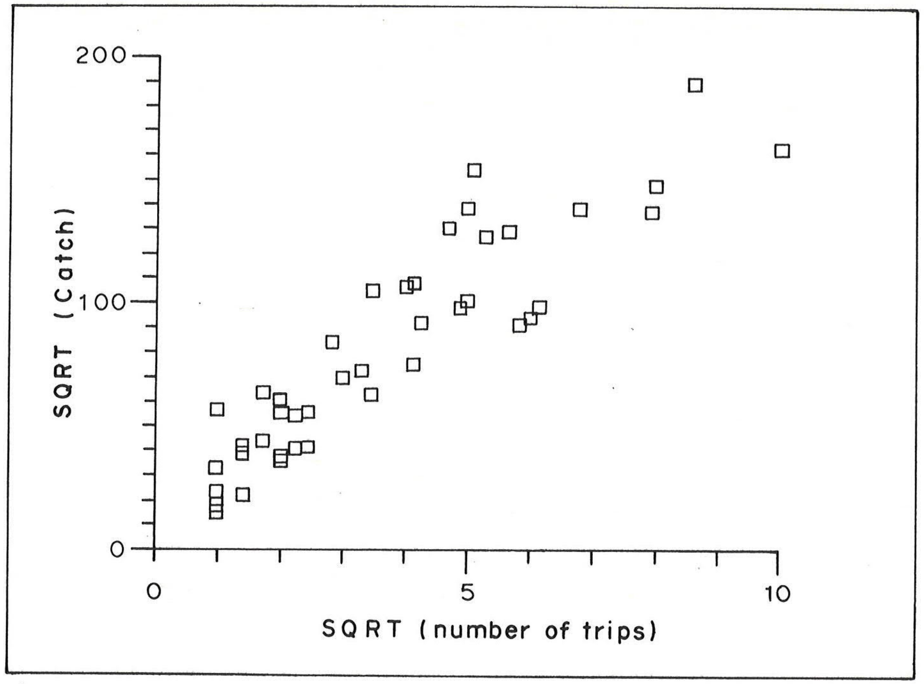

Fig. 2:
Relationship between the square root of the catches of tucunaré (kg) and the square root of the number of trips, per season, of the data of Table 2.

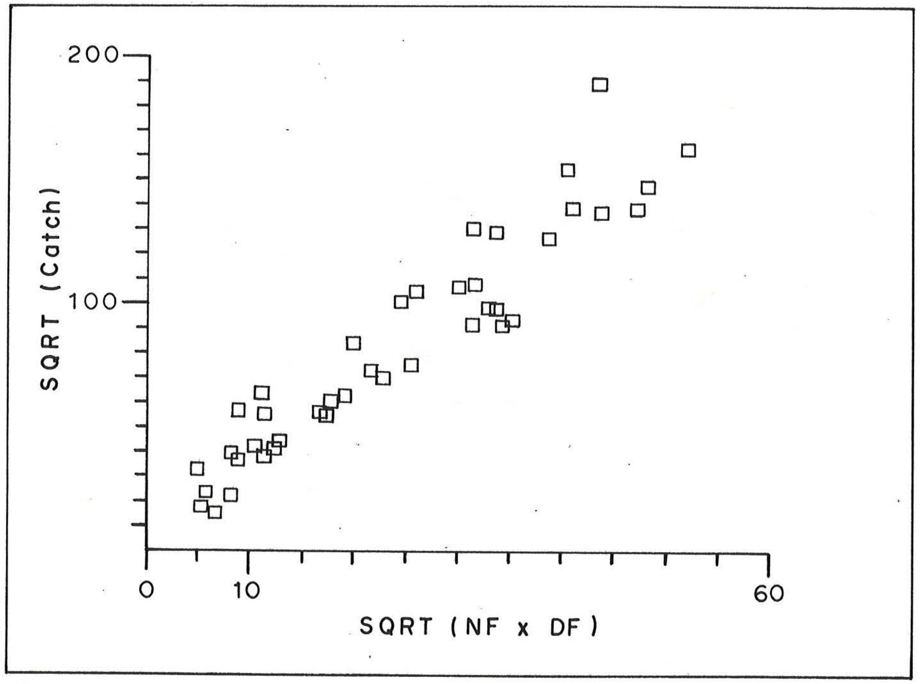

Fig. 3:
Relationship between the square root of the catches of tucunaré (kg) and the square root of the number of fishermen x days of fishing, per season, of the data of Table 2.

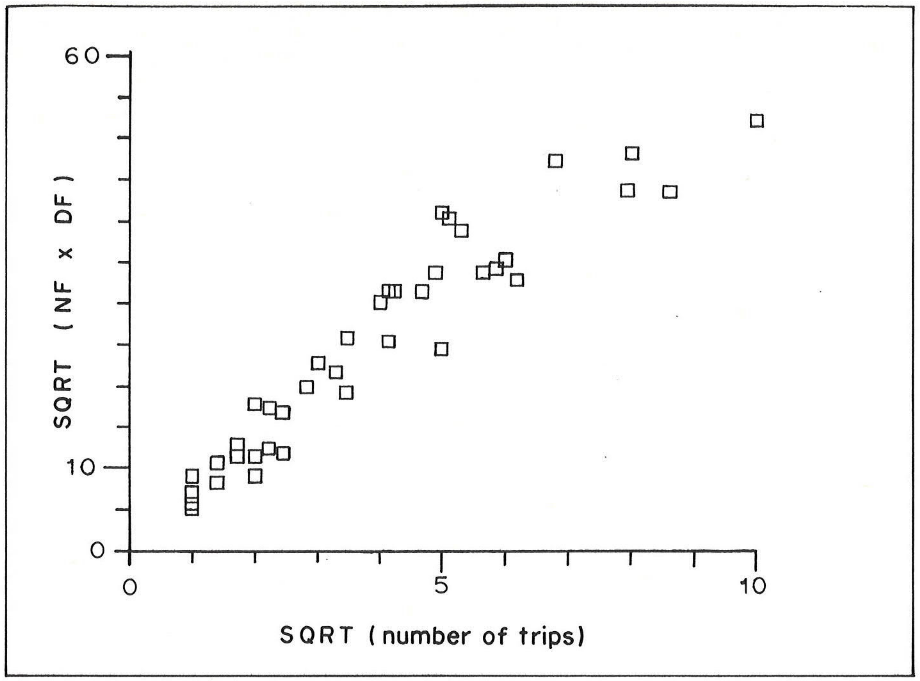

Fig. 4:
Relationship between the square root of the number of fishermen x days of fishing and the square root of the number of trips, per season, of the data of Table 2.

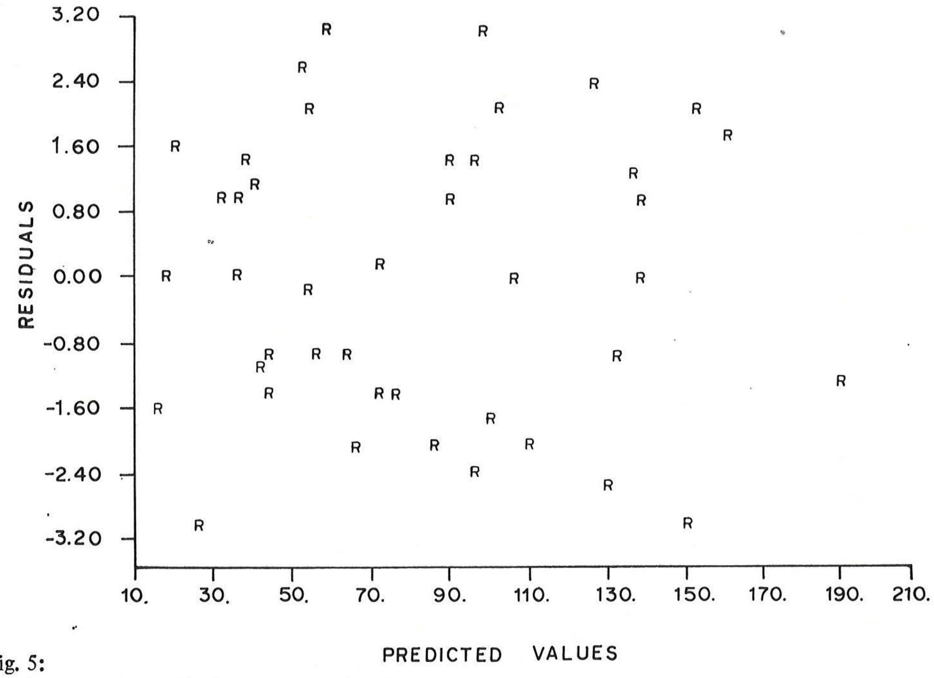

Fig. 5:
Plot between the residuals and the predicted values of the model:

$$Y_{ijk} = \mu + \alpha_i + \pi_j + \gamma_k + (\alpha \cdot \pi)_{ij} + (\alpha \cdot \gamma)_{ik} + (\pi \cdot \gamma)_{jk} + \beta_1 (X_{1\,ijk} - \overline{X}_1) + \beta_2 (X_{2ijk} - \overline{X}_2) + \epsilon_{ijk}$$

when applied to the data of Table 2. See text for definition of the symbols. The print is from the program GLIM (BAKER & NELDER 1978).

Table 3: Results of the application of the FAMC-model to the data of Table 2.

	df	(1) Σx_1^2	(2) Σx_2^2	(3) $\Sigma x_1 x_2$	(4) $\Sigma x_1 y$	(5) $\Sigma x_2 y$	(6) Σy^2	Y adjusted for X df	SS	MS
(01) Total	41	220,66970	7475,06495	1222,59029	3843,16512	23342,43065	81192,06380			
(02) Year	2	1,80984	40,81716	7,57384	- 1,72919	- 70,64543	442,42129			
(03) Lake	6	182,33146	5506,84190	963,94887	3075,96942	17901,33443	59841,31167			
(04) Season	1	7,28270	483,17000	59,31931	97,04292	790,43776	1293,10995			
(05) Year x lake	12	4,48429	205,48014	25,87814	125,41673	848,00230	4781,87264			
(06) Year x season	2	4,85199	318,01128	37,45375	161,80805	1256,62073	5398,09105			
(07) Lake x season	6	11,37845	584,53553	79,98328	154,63181	1174,18718	2803,38335			
(08) Error (YxLxS)	12	8,53097	336,20894	48,43310	230,02538	1442,49368	6631,87385	10	125,02	12,50
(09) (5) + (8)	24	13,01526	541,68908	74,31124	355,44211	2290,49598	11413,74649	22	1126,16	$F_{12,10}$ = 6,67**
(10) (9) – (8)								12	1001,14	83,43
(11) (6) + (8)	14	13,38296	654,22022	85,88685	391,83343	2699,11441	12029,96490	12	227,36	$F_{2,10}$ = 4,09
(12) (11) – (8)								2	102,34	51,1709
(13) (7) + (8)	18	19,90942	920,74447	128,41638	384,65719	2616,68086	9435,25720	16	1804,57	$F_{6,10}$ = 23,39**
(14) (13) – (8)								6	1679,55	279,33
(15) (2) + (8)	14	10,34081	377,02610	56,00694	228,29619	1371,84825	7074,29514	12	1785,45	$F_{2,10}$ = 66,40**
(16) (15) – (8)								2	1660,43	830,22
(17) (3) + (8)	18	190,86243	5843,05084	1012,38197	3305,99480	19343,82811	66473,18552	16	2299,74	$F_{6,10}$ = 28,99**
(18) (17) – (8)								6	2174,72	362,45
(19) (4) + (8)	13	15,81367	819,37894	107,75241	327,06830	2232,93144	7924,98380	11	1160,13	$F_{1,10}$ = 82,80**
(20) (19) – (8)								1	1035,11	1035,11

** = P < 0,01

Table 4: F values for the effects of the treatments year (Y), lake (L) and season (S) and interactions (YxL), (YxS) and (LxS) in the covariates:
X_1 = SQRT (number of trips, per season); X_2 = SQRT (number of fishermen x days of fishing per season), and the response variate: Y = SQRT (catch of tucunaré, kg, per season).
The calculations were carried out in lines 1 - 8 and columns 1, 2 and 6 of Table 5.3.
* = 0.05 > P > 0.01
** = 0.01 > P

Variates Treatments	F value	X_1	X_2	Y
Y	$F_{2,12}$	1.27	0.73	0.40
L	$F_{6,12}$	42.75**	32.76**	18.05**
S	$F_{1,12}$	10.24**	17.25**	2,34
Y x L	$F_{12,12}$	0.53	0.61	0.72
Y x S	$F_{2,12}$	3.41	5.68*	4.88*
L x S	$F_{6,12}$	2.67	3.48*	0.85

3.2 The examination of the Error line

From line 8, of Table 3:

$b_1 = 14.3029$, $sb_1 = 2.8370$, $b_2 = 2.2301$, $sb_2 = 0.4518$.

So $t\beta_1 = 5.04$**, $t\beta_2 = 4.94$**, df = 10, $R^2 = 0.98$.

In this case neither the number of trips nor the number of fishermen x days of fishing can be dropped from the FAMC-model. Both coefficients are highly significant with the same strenght and do not have unexpected signs. Thus, freed from the effect of year, lake and season, and their interactions, the square root of the total number of trips (X_1), the square root of the total number of fishermen x days of fishing (X_2) employed in each season account for 98 % of the error sums of squares of the square root of the catches. The correlation matrix of line 8 is given in Table 5. Note the high values of the correlations between X_1 and X_2, denoting collinearity and the higher correlation between X_1 and X_2 with Y.

Table 5: Correlation matrix in the FAMC-model, where X_1 = SQRT (number of trips), per season; X_2 = SQRT (number of fishermen x days of fishing) and Y = SQRT (catch in weight), per season in kg of the tucunaré (*Cichla ocellaris, Cichla temensis*) data from Table 3 (line 8); df = degree of freedom; ** = P < 0.01.

	X_1	X_2	Y	
X_1	1	0.904**	0.967**	
X_2		1	0.966**	
Y			1	df = 12

3.3 Examination of the goodness of fit of the model:

Figure 5 shows the plots of the residuals of Equation 1 applied to the data of Table 2. There is no clear tendency to non-linearity and heterogeneous variances.

As $Z = 0$ and $b_2 = 1.83^{**}$ D'AGOSTINO (1970), D'AGOSTINO & TIETJEN (1971) the distribution of the residuals is symmetrical but platikurtic, that is flattopped, not normal. But because the 'design' is balanced, theoretically (SCHEFFÉ 1959, ch. 10) the kurtosis is not supposed to affect the level of probability of the F-tests. The signals of the residuals are evenly distributed within treatments. Although there is no way of testing the homogeneity of the regression planes within cells, because there is no replication in the design, the model can still be used with caution in the interpretation of the results.

3.4 The effect of the treatments

Lines 9, 11, 13 in Table 3 show the results of the F-tests for the interactions. Note the high significance of the interactions between year x lake and between lake x season and that the interaction between year and season is almost significant at $P = 0.05$.

Lines 15, 17 and 19 show that the effects of the main factors are very strong.

At the moment we are unable to test whether or not the third order interaction is significant because we do not have an estimate of the error variance independently from the second order interaction. In effect we are assuming that the coefficients of the dummy variables of the second order interactions are zero.

If the second order interaction is significant, the F-tests applied in Table 3 are not exact, but because it is strongly significant and the coefficient of multiple determination in the error line is 98 %, as we saw before, it is unlikely that the conclusion is wrong.

3.5 Calculation of the adjusted means

Because of the presence of strong first order interaction between the effects of year and lake, and lake and season in Table 3, it is difficult to interpret the results of the main effects in the F-test. In this way the adjusted mean catches will be calculated within lakes and season because this is the strongest interaction as tested in Table 3 but they will not be tested in a multiple comparison. The adjusted means are shown in Table 6.

Table 6: Adjusted mean catches (from FAMC-model) within lakes and seasons. The numbers 1, 2, . . ., 7 are related to the lakes Rei, Janauacá, Piranha, Manaquiri, Manacapuru, Aiapuá and Badajós. I – refers to high water season, II – refers to low water season.

Season I	Season II
$L_1 S_I$	$L_1 S_{II}$
$\bar{Y}_{1,\,I\ adj} = 25.630$	$\bar{Y}_{1,\,II\ adj} = 67.396$
$L_2 S_I$	$L_2 S_{II}$
$\bar{Y}_{2,\,I\ adj} = 39.342$	$\bar{Y}_{2,\,II\ adj} = 74.662$
$L_3 S_I$	$L_3 S_{II}$
$\bar{Y}_{3,\,I\ adj} = 66.407$	$\bar{Y}_{3,\,II\ adj} = 97.237$
$L_4 S_I$	$L_4 S_{II}$
$\bar{Y}_{4,\,I\ adj} = 89.926$	$\bar{Y}_{4,\,II\ adj} = 87.234$
$L_5 S_I$	$L_5 S_{II}$
$\bar{Y}_{5,\,I\ adj} = 98.014$	$\bar{Y}_{5,\,II\ adj} = 97.977$
$L_6 S_I$	$L_6 S_{II}$
$\bar{Y}_{6,\,I\ adj} = 110.741$	$\bar{Y}_{6,\,II\ adj} = 105.928$
$L_7 S_I$	$L_7 S_{II}$
$\bar{Y}_{7,\,I\ adj} = 88.836$	$\bar{Y}_{7,\,II\ adj} = 100.040$

4. Discussion and Conclusions

The intensity of the fishing effort is greater in the lakes nearer to Manaus as shown in Table 2. There are at least two reasons for this:

(a) the market puts strong pressure on the freshness of the tucunaré which is normally sold in specialist fish restaurants in the town; it commands the best price for weight at the market along with the pescada (*Plagioscion* spp.) and acará-açu (*Astronotus ocellatus*).

(b) as the trident fishery does not need much capital, a skilful fisherman in a canoe with an engine can easily go fishing for tucunaré and bring it quickly to Manaus to be sold or sell it to a fishing boat at the lake.

Note also that the total catch in the high water season (season I), which amounts 207,467 kg in 507 trips is greater than for the low water season (season II) where the total catch was 156,804 kg in 305 trips. The reason for this is because at high water the fishing effort which was employed in the preceding spawning season to catch the Characoidei is now diverted to the tucunaré. The significance of the effect of the season over the covariates X_1 and X_2 in Table 4 would corroborate this fact. Although the tucunaré is theoretically more difficult to catch at high water in some lakes, since greater effort is required, it is still economic to exploit this fish because of its high price. There are also good facilities in hiring the local populations living in the lakes since farming activity is reduced due to the rising water levels.

The strength of the significance of the interaction between lake and season in Table 3 can be explained by considering three joint effects:

(i) the behaviour of the fish

(ii) the way the trident fishery operates

(iii) the differential effect of the fluctuation of the level of the water in the lakes due to their distinct morphologies and vegetation cover.

As mentioned previously the tucunaré is caught with trident during the night because it is usually found inactive (ZARET 1980) in low water close to the lake shore or in the shallower parts of the inundated forest in the high water season. So shallow lakes which have greater littoral zones provide more favourable habitats for the tucunaré. Adjacent floodplains provide a similar environment and with reduced vegetation cover, a falling water level in these floodplains would improve conditions for the capture of the tucunaré. In the set of the lakes of Table 1, lakes Badajós and Manacapuru are blackwater lakes of 'terra firme' and are deeper than the rest of the set. Shallower 'várzea' lakes would contribute much more fish with a comparable amount of effort than a 'terra firme' lake in similar stock conditions in the low water season.

The significance of the interaction between year and lake in Table 3 is perhaps due to the fact that 1976 had exceptional floods.

In Table 6 one sees that there is a tendency for the adjusted mean catches to increase the farther one gets from Manaus in both seasons. The reason for this are probably historical and probably also due to changes of the fish behaviour in learning how to avoid the trident fishery tactics, although at the moment we do not understand how the fish would do it.

There is still no evidence from the analysis for differences in productivity between blackwater and whitewater lakes, because those of the two blackwater lakes are in an intermediate position. If differences in productivity exist, one can expect the adjusted means for the catches in blackwater lakes to drop more rapidly than in whitewater lakes in the future.

Note again in Table 6 how the adjusted mean catches between seasons give an interesting pattern: although they are higher in season II in lakes 1, 2, 3, 7 the opposite occurs in lakes 4, 5, 6 although differences in the second set are small. This agrees with the interaction between lake and season seen in Table 3.

The result will be more complicated if the planes of the two different seasons (whithin cells) are not parallel although we cannot test for this at the moment. So the expected result that the adjusted mean catches in the low water season are greater than in the high water season is not always satisfied, as it varies in different lakes. As mentioned earlier, this is probably due to historical reasons, because lakes nearer to Manaus have been submitted to a more intensive fishing for a longer period of time.

Due to the changing character of the fishery, the results of the present analysis should be cautiously extrapolated in time and in fishing effort.

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